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ABSTRACT

The concept of Computer Integrated Manufacturing (CIM) is largely accepted to be the foundation on which manufacturing companies should build the Factory of the Future. Flexible Manufacturing Systems (FMS) are used as a major element in a technology-push strategy pursued to obtain a competitive edge by focusing on flexible production automation. In this paper we discuss the need for corporate policy makers to link their technology-push strategy with their global business strategy and base their decisions to invest in flexible automation on sound arguments.

1. INTRODUCTION

Manufacturing ranks among the principal real-wealth producing activities of most industrialized countries. It has been estimated (Hatvany et al. (1983)) that manufacturing indeed accounts for about one-third of the gross national product. Various forces seem to push the manufacturing industry towards an increasing reliance on technology as a means for developing a competitive edge.

First, there seems to be a general agreement that technology is a major contributor to productivity, even though there may be considerable differences of opinion on the actual amount of the contribution (e.g. according to Myers (1983), estimates of the contribution of technology to improvement of productivity in the United States have varied from 30 percent to 80 percent). In addition, management faces the disturbing fact that inefficient production technology is often cited as one of the main reasons for closing a plant. A recent survey of 171 of the more than 1,000 plant closings by Fortune "500" industrials during the 1970s for example, reveals that, while drops in sales volume and high labor costs contribute to many plant closings, the clear culprit in closings of both new and old facilities, is an inefficient production technology (Schmenner (1983)). In nearly half of all closings (46 percent) the factory slipped into inefficient or outdated production technology, layout, or materials handling.

Second, corporate policy makers face the fact that especially in discrete part manufacturing there is much potential for serious cost reduction

(Herroelen (1983)). Carter (1972) has shown that, when the life of the average work-piece in small-batch metal cutting production shops is analyzed, only about 5 % of its time is actually spent on machine tools, and of that 5 %, only about 30 % (or 1.5 % of the overall time) is actually spent as productive time in removing metal. This supports the view that many Western small-batch manufacturing job shops, although very flexible, can hardly be called efficient or productive. While in the traditional Western view, flexibility and efficiency are 180 degrees apart, in the Japanese approach the two seem to be only 30 degrees apart - more in harmony than in conflict (Schonberger (1983), Wheelwright (1981)). This apparent success of the Japanese manufacturing industry, relying largely on flexibility and integration, together with the increasing world business competition are crucial incentives for the many recent efforts to renew the manufacturing effectiveness of the Western World. The apparent conflict between manufacturing flexibility and productive efficiency which has long bedeviled the industry, seems no longer inevitable. The so-called <u>Factory of the Future</u> is now cited to be the key to this renewal and is accredited to hold all potentials to resolve the conflict.

It is a firm belief that the Factory of the Future will evolve primarily through successive refinement and integration of existing design and manufacturing functions and technologies. The concept of <u>Computer Integrated Manufacturing</u> (CIM) is largely accepted to be the foundation on which manufacturing companies should build this Factory of the Future (Gunn (1982)). CIM represents the integration of information technology with robotics, automated materials handling, the use of computers in design (CAD) and manufacturing (CAM), modern manufacturing planning and control systems and the principles of cellular production based on group technology. Flexible Manufacturing Systems (FMSs) - the Japanese increasingly use the term Factory Mechatronics Systems (Tsuda (1983)) - are crucial links in this integration.

In general, a full-fledged flexible manufacturing system (FMS) consists of a group of processing stations - numerically controlled machines, machining centers with automatic tool interchange capabilities and robots - linked together with an automatic material (workpart) handling system, that operates as an integrated system under computer control (Herroelen (1983)). FMSs are designed and developed to produce small- and mid-sized batches of several different part types with the efficiency of automated mass production (transfer lines) and the flexibility of a job shop. The FMS is considered as a crucial technology-push strategy for a discrete parts manufacturing company that wants to obtain a competitive edge by focusing on flexible automation.

It is the purpose of this paper to discuss the need for corporate policy makers to link their technology-push strategy with their global business strategy and to base their decisions to invest in the emerging production technologies on sound arguments. In discussing how this may be accomplished, our argument is developed in the following steps. In the next section we discuss some crucial implications of a technology-push strategy and contrast it with a more market oriented demand-pull strategy, reaching the overall conclusion that an offensive use of flexible production automation enables a company to pursue a combination strategy which brings to bear many beneficial strategic factors. According to our arguments that investments in flexible automation require a careful analysis, the third section elaborates on the basic ingredients of the required investment analysis and the intelligent use of the discounted cash flow method. The last section is then reserved for our overall conclusions.

2. IMPLICATIONS OF A TECHNOLOGY-PUSH STRATEGY

Previous research suggests a strong relationship between the characteristics of a product and its manufacturing process. According to the arguments of Abernathy (1978), Hayes and Wheelwright (1979a, 1979b) and Utterback and Abernathy (1975), manufacturing processes, no less than products turned out, go through a life cycle evolution. Initially non-standardized, often exclusive products are manufactured using uncoordinated, often manual production processes. The product innovation rate is high and is stimulated by an expanding market demand, the ultimate potential of which is not yet fully recognized. The required product innovation insights are obtained mainly by recognizing the relevant product requirements rather than by new scientific developments or advanced technologies. As the industry further develops, market uncertainty declines. Gradually a dominant product design evolves, reducing the need for real product innovation. Competition in mature markets is now largely based on low prices. This invokes further process innovations.

As price competition increases, the production process becomes more capital intensive focusing on low-cost production. This finally leads to a rigid state characterized by only marginal product and process innovations.

It has been argued (Ferdows (1983)) that a productive unit, evolving primarily along the lines explained above, may be caught in a vicious circle which demands more investments while profitability declines. Various strategies may be used for avoiding or breaking out of the vicious circle. In particular, the technology-push strategy which focuses on flexible production automation in order to increase the manufacturing flexibility to be able to produce more diverse products or change volume throughput, lies at the heart of the Flexible Manufacturing Systems concept - nowadays cited as the "lifeline to 21st century manufacturing technology" and a crucial link in the evolution towards the Factory of the Future. Such a strategy implies that the productive unit aims at combining the inherent flexibility of job shop production with the efficiency of flow and transfer lines used for mass production. For a thorough review of the technology behind such a combination, we refer the reader to Herroelen (1983). As already mentioned above, flexible manufacturing systems and the use of reprogrammable robots show great promise in this respect. The overall concept of Computer Integrated Manufacturing (CIM), integrating computer aided design and manufacturing (CAD/CAM), robotics, automated materials handling, cellular production principles based on group technology, suitable production planning and control and advanced local area network computer technology, holds the promise to adapt faster to volume throughput changes and product differentiation and allows to increase the reliability, quality, and customer service at a competitive price.

Employing flexible manufacturing technology as an integrated, offensive strategy is a major departure from the traditional view, which merely uses technology as a basic element in a rather protective strategy to achieve overall cost leadership in an industry. This narrow-minded view of becoming a "low-cost producer" is vulnerable to various risks. If no sufficient care is taken in pursuing a technology-push strategy, technology-push may turn out to be a technology trap.

The pitfalls of technology based cost leadership

Overall cost leadership, the first generic corporate strategy listed by Porter (1980), is based on exploiting the scale economies associated with high-volume production, positioning the productive unit as low as possible on the learning curve, vigorous cost control and extensive investment in equipment and machines. Such a strategy requires a high relative market share and management expertise with respect to production engineering, production management and inventory control.

A strategy which overemphasizes technology-based cost leadership is subject to many risks, among which the following two deserve our special attention. First, process technology is not necessarily an entry barrier. People often move from one firm to another carrying their employer's process technology with them (Zannetos (1984)). Industry newcomers or followers may take advantage of low-cost learning through imitation or through their ability to invest in state-of-the-art facilities (Porter (1980)). Newcomers may soon reach the same learning curve position as firms that have been operating in the industry for a long time. The $ 1,500 cost advantage of Japanese over Western car producers illustrate this point (Abernathy, Clark and Kantrow (1983)). Steel production provides another illustration : the cost advantage of the U.S. over Japan which existed in 1956 has been transformed into a net cost disadvantage in 1976 (Thompson (1984)). Second, a number of cost elements are heavily influenced by external factors such as inflation, labor force agreements on wage level and working hours and increasing raw material prices. Such an inflation in costs is largely beyond management control and may seriously hamper a cost leadership strategy.

Increasing capital intensity and lower return

Employing technology as a strategic tool leads to an increase in capital intensity. Recent studies (Gale (1980), Porter (1980)) have shown that very capital intensive firms are not necessarily characterized by a greater earning capacity, mainly due to the following reasons. First, capital intensive firms focusing on low cost production and overall cost leadership, may become the victim of an agressive low price competition with negative effects on company return especially during periods of depression and underutilization. Second, a technology based strategy leads into increased fixed costs which is normally translated into higher company risk. Third, where process technology is not necessarily an entry barrier, the resulting increased capital intensity may become an important exit barrier. Decisions to disinvest are very complicated, especially when heavy investments have been made in dedicated, specialized equipment.

The implications of vertical integration

Apparently the impact of automated manufacturing in general and of Flexible Manufacturing Systems (FMSs) in particular is mainly found in small and medium batch production, more precisely the manufacturing of elementary parts and components. As such, automated manufacturing may hold strong tendencies towards vertical backward integration. A productive unit may indeed be tempted to install flexible automation within its own confines in order to reap the benefits of controlling and coordinating the manufacturing and delivery of components and parts. Vertical backward integration indeed has important generic benefits (Porter (1980)) such as lower transaction costs, reduction in the uncertainty of supply and deliveries, better coordination in establishing production plans and controlling production schedules and better technical cooperation and tuning of the operations in case of innovation and launching of new products.

However, there are also some risks involved with a high degree of vertical backward integration. First, vertical backward integration requires heavy investments. Investment intensity (investments as a percentage of sales turnover) is known to increase with increasing degree of vertical backward integration (Buzzell (1983)). Second, the efficient scale will be different for assembly than for component manufacturing. As mentioned by Porter (1980), the volume of purchases of the firm contemplating backward integration must be large enough to support an in-house component supplying unit large enough to reap sufficient economies of scale in manufacturing the parts and components, or the firm faces a dilemma. Either it must build an in-house facility at a serious cost disadvantage, or it must bear the possible risk of selling some of the production of the upstream unit in the open market. Hence the firm must analyze whether it is not better to rely on subcontractors for the supply of parts and components. The subcontracting task can be accomplished by a small or medium sized firm that may reach an efficient scale by performing the subcontracting activity for a number of companies within the same sector.

In short it should be mentioned that a high degree of vertical backward integration is mostly translated in lower return, unless the firm has a relatively large market share. This is in strong contrast with vertical forward, customer oriented integration, for which the investment requirements seem to be lower and which indeed has a positive effect on company return.

Technology-push and demand-pull

The above remaks concerning the risks involved in employing technology mainly to achieve overall cost leadership stand in strong contrast with the advantages generally attributed to a more market-oriented, demand-pull, differentiation type of strategy. Differentiating the product or service offering of the firm is listed as the second generic strategy by Porter (1980). This strategy tries to obtain a unique product position within the industry through the creation of an exclusive brand image, brand loyalty by customers, an emphasis on customer service and an efficient dealer network, quality promotion or technical product superiority. Such a strategy requires strong marketing abilities, leadership in product design and engineering and a lot of creativity. Differentiation, if achieved, is a viable strategy for earning above-average returns. Although not ignorable, costs are no longer the primary strategic target. This type of demand-pull strategy is generally evaluated as successful (Peters and Waterman (1982)).

Until recently, the overall cost leadership and the differentiation strategy were largely considered to be incompatible. Either a productive unit operates as a rather rigid cost leader without achieving differentiation, or it gains flexibility through differentiation at the price of loosing overall cost leadership. Automated manufacturing, in particular the use of flexible production automation, allows to resolve this dilemma and enables a company to pursue a type of combination strategy. As stated by Skinner (1984), this can bring to bear many other strategic factors besides achieving low cost; to wit, superior quality, shorter delivery cycles, lower inventories, shorter new product development cycles, and new production economics, allowing for a richer product mix, more product proliferation and more customer specials.

Using computerized manufacturing and flexible automation as a powerful competitive weapon cannot be done without a careful economic evaluation and a thorough analysis of the investments involved.

3. THE INVESTMENT DECISION

A. What is different about investing in production technologies

The investment in production technologies certainly is a strategic issue whose impact goes far beyond the strict evaluation of the equipment itself. A number of benefits are sometimes extremely difficult to measure such as improved manufacturing flexibility or benefits due to integration synergy. The introduction of computer aided manufacturing equipment influences the total organisation, the manufacturing system and certainly the type of products offered by the company. The risk position of the company may be changed because of uncertainties in market prospects and maybe because of changes in the cost structure due to a shift from variable to fixed costs. Because of all these factors mentioned above some people started having doubts about the suitability of the traditional capital budgeting techniques. We believe that this doubt is misplaced, we still have to depend on traditional capital budgeting techniques, such as discounted cash flow, to evaluate such proposals. What is needed is a much broader level of analysis (Gold (1982)) than the one traditionally used in evaluating the purchase of a machine or single piece of equipment. A too narrow view on the problem may either defer or even reject the purchase.

In a recent article Kaplan (1983) states that "... a narrow interpretation may inhibit desirable investment projects. There is a danger from relying solely on the easily quantified savings in input factors, such as labor, energy, and materials, from new capital investments and not considering gains from improved manufacturing performance that are more difficult and subjective to quantify. Factors such as improved product quality, increased manufacturing flexibility, reduced inventory levels and the capacity for increased product innovations may be ignored because we have inadequate means for quantifying their benefits". Bylinsky (1983) believes that one consequence of this myopia is apparent in the aging of the U.S. machine tool stock.

As already suggested above, the investment in flexible manufacturing systems is a strategic decision and not a simple replacement problem. For the moment there is a missing link both in practice and in research between the firm's manufacturing strategy and the measurement of the manufacturing performance and the impact on the total organization. Just to illustrate this point we mention a number of unsolved problems. What is the relationship between higher quality and (lower) costs ? What is the impact of flexible production automation on sales ? How to measure for example the inventory reduction through the introduction of a just-in-time system, which is made possible by flexible automation ? What is the impact of improved manufacturing practices on the uncertainty in lead times and scrap rates and consequently the investment in safety stocks; in other words, what is the trade-off between reducing uncertainty and the investment in safety stocks ?

B. The ingredients of a good investment analysis

A good investment analysis must include the following considerations.

1. Manufacturing policy and product strategy.

Manufacturing costs are not always of primary importance. Competitive emphasis may be on marketing or on the development of unique high performance, high technology products. On the other hand, a low cost strategy may be imposed on the company forcing it to keep manufacturing costs at a minimum. The precise nature of the manufacturing system tasks will be different in both situations. This illustrates that one of the most important top management decisions has to do with the matching of manufacturing policies and product strategies. This choice problem is beautifully described by Stobaugh and Telesio (1983). The answer to the question determines whether computerized manufacturing is an important issue or not. In this article, we assume that the company operates in an industry characterized by tough price competition, high quality standards, and a reliable delivery performance, making it necessary to pursue a low cost strategy.

2. Cash flow analysis.

It has been shown by many authors that accounting ratios such as return on investment or return on equity or earnings per share have serious shortcomings as financial standards to evaluate strategies or major investment proposals. Rappaport (1981) analyzed the Standard and Poor's 400 industrial companies during 1974-1979. In 16 % of these companies stockholders realized negative rates of return from dividends plus capital losses and 35 % of the 172 companies stockholders' returns were inadequate to compensate just for inflation. The point is that reported earnings are highly sensitive to accounting evaluation rules such as the LIFO and FIFO rule, historical costing or current costing. Capital expenses are depreciated over a number of years and are deducted from profits. Sometimes a time lag exists between the moment a liability is incurred and the moment the bill has to be paid, the same is true for payments of customers. These examples illustrate that companies can create net income in different ways, one way is by changing accounting conventions, this of course is not a good measure of the underlying economic health of the firm.

The real measure of management success or the economic value of any investment is simply the anticipated cash flow discounted by the cost of capital. The discounted cash flow method considers besides the time value of money also the aspect of risk. The economic value to shareholders of alternative strategies can be assessed by estimating future cash flows. Although some authors, consultants and managers may have some doubts about the applicability of the classical investment analysis tools, we argue that these techniques are still extremely important.

3. Computerized manufacturing is still in an embryonic stage of development.

For the moment not much experience has been gained in relation to investments in flexible automation equipment. Developments are still in an "embryonic" stage characterized by a high risk. Flexible automation projects are very risky at inception. The exact nature of the typical implementation problems has not extensively been documented so far. Correctly estimating the relevant cash flows in a hard nut to crack. The attitude towards risk depends, among other factors, on the financial position of the company. This financial position depends on the current and planned product/market portfolio. Top management must take care that the cash balance is maintained. This again illustrates the need to integrate the analysis in a company wide strategy.

4. Computerized manufacturing as an epidemic process.

The installation of integrated flexible automation equipment is not a static, once and for all type of decision. On the contrary it is a dynamic integrated type of decision. It is a time-phazed, continuous process in which capital outlays will be spread maybe over a 10 year time horizon.

Revenues will not be generated immediately, the implementation stage may take a long time. We have to ask managers to look into a far future and mechanical extrapolations of data in the past are of no help. Again this stresses the need of integration and a company wide view of this almost epidemic process.

5. The need for a "what if not" analysis.

Managers must include a "what if not" analysis. Suppose that a company decides not to invest in flexible automation. What are the consequences in terms of the competitive position of the firm ? What happens with the future cash flow ? What is the risk of being completely dominated by a competitor ? What are the company survival chances if it cannot compete with other low-cost companies ?
Figure 1 illustrates two somewhat hypothetical cash flow streams for a typical productive unit resulting from two opposite scenarios. Curve (a) represents the resulting cash flow stream given the scenario that the productive unit does not accept the proposals to invest in flexible production automation, while curve (b) denotes the cash flow stream for the opposite scenario.
Although Figure 1 possibly refers to a somewhat extreme case, it clearly illustrates the possibility that the Net Present Value of scenario (a) is higher than the Net Present Value of scenario (b) given a specific time horizon and a specific discount rate. That is the dilemma faced by many companies

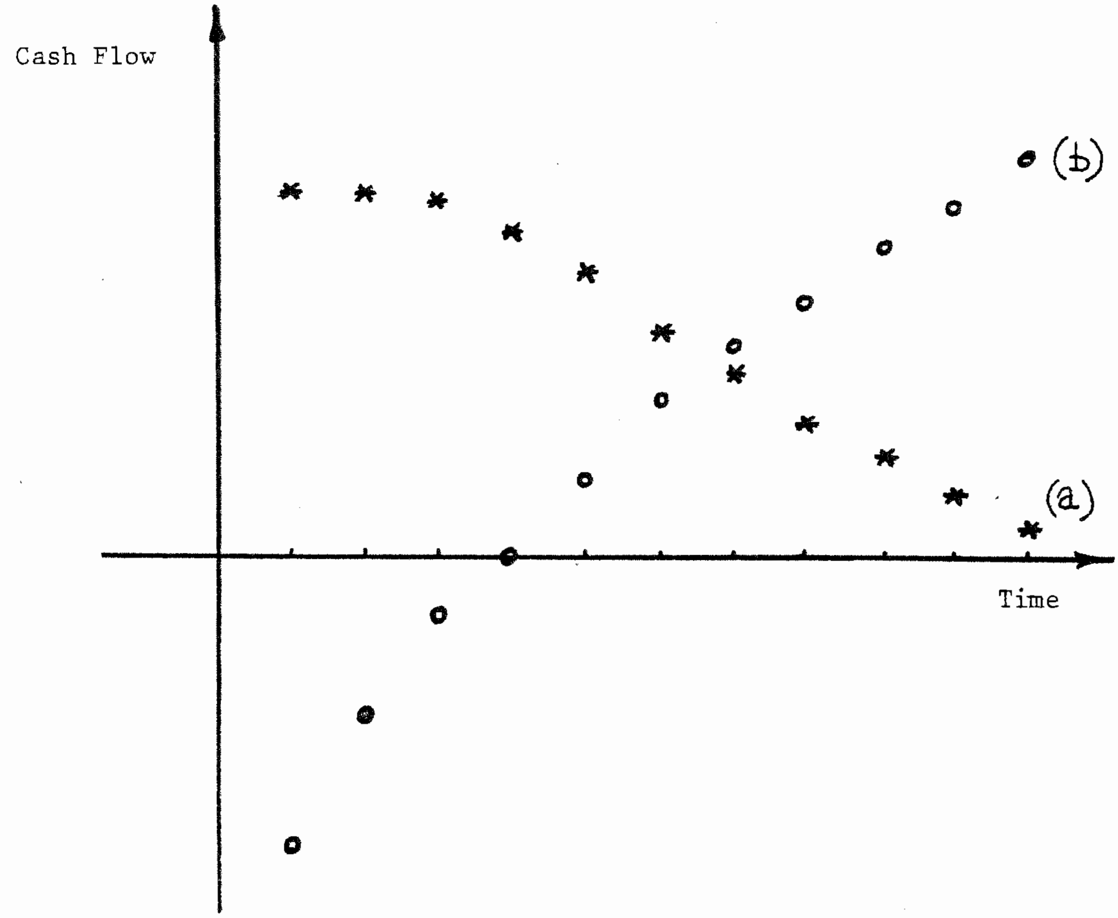

Figure 1 : Cash flow stream for a company accepting (b) and rejecting (a) flexible automation.

and at the same time it is the source of criticism launched against the Discounted Cash Flow method. Who is indeed willing to strive against the stream ? What can be done about the observation above ? Of course managers should strive for a correct application of finance theory. First the time horizon needs to be selected very carefully. Given the dynamic, epidemic and almost contagious process, managers must be aware that computerized manufacturing implies long term investments (10 - 15 years). Second, one has to be careful in selecting the discount rate (Myers (1984)). Our inability to look far into the future should not be translated into an unrealistically high discount rate. An investment analysis always starts with a forecasting exercise; this can be very difficult but it must be done. The discount rate must take care of the risks involved; it must account for the fact that the company shifts from a variable cost production system to a more fixed cost production system. It must also take care of the sensitivity of an investment's return to market movements. As was mentioned before, flexible automation investment projects are usually risky at inception but only of normal risk once the start-up is successfully passed. There are also high risks involved in case the company decides not to invest. All these observations must be included in the analysis. The best way to handle the problem is to go through a sensitivity analysis. Third, the curves in Figure 1 are highly influenced by the timing of the introduction. A project can be postponed for a year or more. Postponing the project is not necessarily a bad thing to do. More experience may become available, the prices of the equipment may go down, the software may become more reliable, a turn-key system may become available and so on. On the other hand, the decision to wait may hamper the company's competitive position. The company may loose its market share and even face the risk of being ruled out of business.

6. Production is more than making costs.

A final remark dealing with the investment in production technologies has to do with the estimation of the cash flows. The central idea is that production is much more than making costs. We too often evaluate proposals based on cost criteria. The impact of automation on market share is often neglected. Quality improvement has to do with the competitive position and consequently with market share. A reduction in lead times is a competitive weapon which is finally rewarded on the market place. The same holds for shorter new product development cycles and a richer product mix. Managers are often surprised by the fact that the current ratio of inventory to sales is no better than it was 20 years ago. From a cost point of view, it seems that we are doing a lousy job. The reason for such an inventory behavior can be explained by the fact that service improved and that companies offer a much greater product variety. Flexible automation is more than a technology-push strategy, rather it is a means to combine the technology-push strategy with a demand-pull strategy.

Of course, the cost aspects cannot be excluded from the analysis. It is important, however, to concentrate on the right costs. On the average the structure of total manufacturing cost is as follows : 10 % direct labor, 40 % indirect costs and 50 % materials. There are potential cost reductions for all three categories. The most difficult one to manage, however, are the indirect costs. That is exactly where most companies fail. Companies underestimate e.g. the time it takes to implement the system; the organisation must be changed, employees must be trained, a tremendous amount of software must be developed, inventories will not go down automatically and so on. So there are plenty of reasons for a careful cost analysis. But as mentioned already, production and automation is more than making costs; top management must be convinced that flexible automation is generating cash as well.

IV. CONCLUSIONS

Corporate policy makers face the need to link their technology-push strategy with their global business strategy. Employing flexible manufacturing technology as an integrated offensive strategy is a major departure from the traditional view which merely uses technology as a basic element in a rather protective strategy to achieve overall cost leadership. Such a strategy, if used properly, may enable a productive unit to avoid or break out of a vicious circle which demands more investments while profitability declines. It essentially allows the flexibility of small batch production to be combined with the efficiency of mass production and triggers many other strategic factors besides achieving low costs.

Decisions to invest in flexible automation and computer integrated manufacturing systems must be based on sound arguments. Arguing that an intelligent use of the discounted cash flow method, combined with an overall strategic view, provides the basic course of action, it was emphasized that production is more than merely making costs and that flexible automation investments involve a dynamic, integrated type of decision.

The arguments developed in this paper should have made it very clear that the evaluation of investments in new technologies is a complex and risky task and certainly involves strategic decisions on the precise technology-push course to be followed. When a manufacturing company faces competitors who are avoiding or breaking out of a dangerous vicious circle by moving very fast towards the introduction of flexible manufacturing technology, it should realize that those competitors got away with the evaluation problem and are constantly acquiring a competitive edge. One of the crucial questions to be answered then is simply what will happen to the productive unit if the required investments in flexible manufacturing technology are not made.

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